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Learning by Doing:
The Role of Active Learning in the Reform Movement

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Abstract:

One of the hallmarks of reform mathematics classes is that students are actively involved in the learning process. They perform experiments, they collect data, they work on projects with other students, they conduct and write up labs. This panel, consisting of one faculty member and three students, will discuss some of the ways in which students have become active participants in their mathematics classes here at Hood College.

In teaching mathematics, I have rarely stood at the front of the room and lectured, while my students sat passively in their seats and took notes -- and I'll bet you haven't either. For most of us, teaching is a kind of dialogue: we write something on the board and ask the students what they make of it, they respond, we continue, they interrupt with questions... We are engaged in a discussion with our students, and I would have said that they

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were active participants in the classroom, and actively involved in the learning process.

But my notion of what constitutes "active learning" was cranked up a notch when I attended a Project CALC workshop several summers ago at Duke University. And that's what I'd like to talk about today. Here are some of the things we do in mathematics classes at Hood now that I think of as "learning by doing":

Classroom demonstrations and experiments

We bought some Vernier hardware and software which allows us to use a motion detector to track a student's distance and velocity as she walks across the room, and graph them on a computer screen in real time, so we can look at the graphs and talk about possible relationships between them. We can take a temperature probe and plunge it into a hot cup of coffee, or a glass of ice water, and look at a graph of temperature over time, then talk about its shape, and try to fit a curve to it.

My students still try to find that open-top box with maximum volume by cutting the corners from a piece of cardboard, but we actually make those boxes -- I hand out pieces of paper, and students cut out squares of different sizes from the corners, and tape the sides up to make boxes, so that the classroom is soon littered with boxes of different sizes. We talk about the different shapes of the boxes, and try to predict which will have the largest volume. Then, of course, we can compute the volumes, pick the winner, and go on to talk about how to generalize the problem and solve it using graphs and derivatives of functions.

Computer labs

We have a two-hour computer lab scheduled every week in each semester of the calculus sequence. The students investigate all sorts of problems -- population growth, the path of a mortar shell, the spread of an epidemic -- using real, messy data. They work in pairs, and a lot of arguing and

discussion goes on in the labs as the students discover results and write them up in lab reports.

Group projects

Often in class, we will stop and break up into small groups and work problems or investigate a new concept, with the students "in charge" instead of the instructor. And several times during each semester, students do large-scale projects in groups of three or four. They may do research in the library, perform experiments, and use the computer. Some examples are: learning about radiocarbon dating; using a topographical map of Yosemite National Park to find the path of steepest ascent from one point to another; discovering the similarities among electrical circuits, cooling bodies, and falling raindrops.

Reading and talking (and writing) about mathematics

I think the hardest part, for me, of teaching mathematics in this "new way" has been to encourage my students to read the textbook before coming to class -- to allow them to steal my thunder, to anticipate results before I have revealed them in class. Students are taught to "read actively" -- to keep a pencil with them when they read, to make notes in the margin, to stop and work problems along the way to make sure they understand, to read and re-read. And because students always work in lab with a partner, and work so often in groups, they must talk about mathematics. They are not allowed to be passive learners in a class like this.

Student presentations

Three of my students are here with me today to tell you about some of their favorite activities in math classes.

Aba Blankson has just completed her freshman year at Hood, and took Calculus I and II this year. She is going to talk about a couple of class experiments we did on the very first day of class

in Calculus I, two experiments straight out of the Project CALC instructor's guide.

Superball experiment: students bounce a ball, measuring its initial height and bounce height. We collect lots of data and make a scatterplot on the classroom computer. As a class, we look for patterns and fit a straight line to the data.

Pendulum experiment: students make a pendulum out of a doorknob and a piece of string. For different lengths of string, they time how long it takes for the pendulum to swing through ten full swings. Then, again, we collect the data and make a scatterplot of period vs. length of string. This time the relationship is not linear; we fit a more complicated model to the data.

Julie Ayres just graduated from Hood as a mathematics major. She will talk about two group projects she participated in when she took calculus.

Centers of mass project (Calculus II): Students discovered properties of centers of mass in one and two dimensions. For the one-dimensional part, students balanced a wooden dowel on a bracket and then balanced metal washers on each side (3 at a distance of 2 on one side, and 2 at a distance of 3 on the other side, for instance). For the two-dimensional part, they took cardboard cutouts of planar regions (like the region between the curve y=3Dx2 and the x-axis, for x between 0 and 1) and balanced each one on a pencil eraser. They wrote down the coordinates of this balance point and then worked on some discovery exercises, drawing regions and filling them with rectangles and summing the centers of mass of each rectangle, to come up with a theoretical formula for the center of mass which they could compare with their collected data.

Spirograph project (Calculus III). Students drew pictures with a Spirograph and then found parametric equations to represent the curves they had drawn. To check their work, they used the computer to graph the parametric curves.

Izzy Kyle has just completed her junior year at Hood; perhaps you recognize her from her photo in the last issue of Math Horizons. This past spring, she was a student in my differential equations class, which I taught using the new textbook by Blanchard, Devaney, and Hall. This is a textbook which will appeal especially to students who have taken calculus from a reform text, and who are accustomed to doing projects and using a computer, and who expect to solve problems in lots of different ways -- students who have been NAGged. She is going to talk about two projects from that course.

Rate of memorization project. In groups of two, students timed how long it took them to memorize a list of numbers. They collected data and then fit a curve to the points, using a learning curve model we had discussed in class.

Moldy bread project. Each student took a piece of bread and grew mold on it. Using a transparent grid, she counted how many squares were covered each day until the entire piece of bread was covered. She then fit a mathematical curve to the data, comparing exponential and logistic models to predict the growth.

Conclusions

Using "active learning," letting students discover things on their own, is certainly a lot more work than just telling them everything myself. But I have to believe that it's better for them in lots of ways.

It keeps them awake in class! It involves them in ways that they may not have been involved in a mathematics classroom before.

It places the responsibility for learning squarely on their shoulders. They must read the textbook and be prepared to ask questions if they don't understand; they must come to class and to lab, ready to participate; they must think about how to design experiments and write them up.

If we believe the literature on the subject, we have to believe that students learn better, and remember things longer, when they are actively involved in the process.

And, most important of all, this way of teaching, and of learning, is so much fun! I hope we have given you a glimpse of how exciting this kind of learning is. Once you have tried it, I don't think you'll ever want to go back.